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**Liu**

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(54) **POWER SEMICONDUCTOR DEVICE AND  
EDGE TERMINAL STRUCTURE THEREOF  
INCLUDING AN L-SHAPED  
ELECTRIC-PLATE**

(58) **Field of Classification Search**

USPC ..... 257/483, 484  
See application file for complete search history.

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(57) **ABSTRACT**

An edge terminal structure of a power semiconductor device is provided that includes a substrate, a first and a second electrodes disposed on a surface and a back of the substrate respectively, a first field plate, and a second field plate. The power semiconductor device includes an active area and an edge termination area, and there is a trench in a surface of the substrate in the edge terminal area beside the active area. The first field plate is disposed on a sidewall of the trench and extends on a tail of the trench, and it includes at least a L-shaped electric-plate, a gate insulation layer under the L-shaped electric-plate, and the first electrode on the L-shaped electric-plate. The second field plate includes at least an insulation layer and the first electrode thereon. The insulation layer covers the tail of the trench and a tail of the L-shaped electric-plate further.

**10 Claims, 3 Drawing Sheets**

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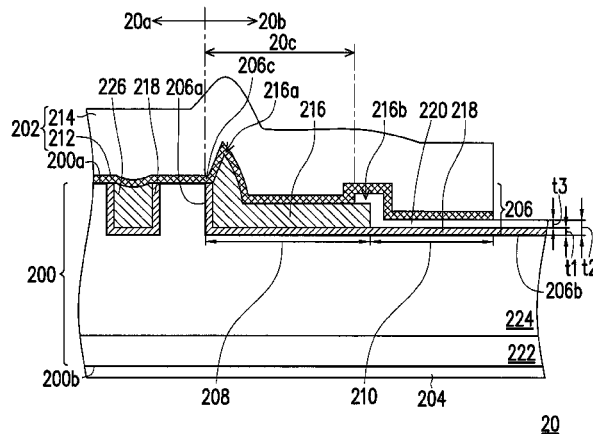
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(52) **U.S. Cl.**

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# US 9,153,652 B2

Page 2

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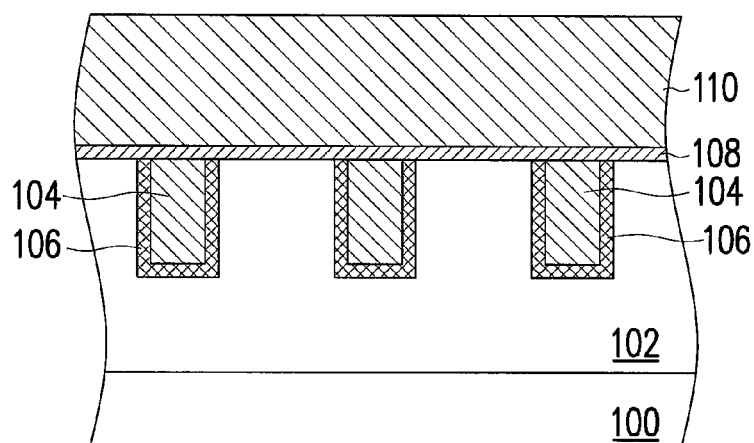
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FIG. 1 (RELATED ART)

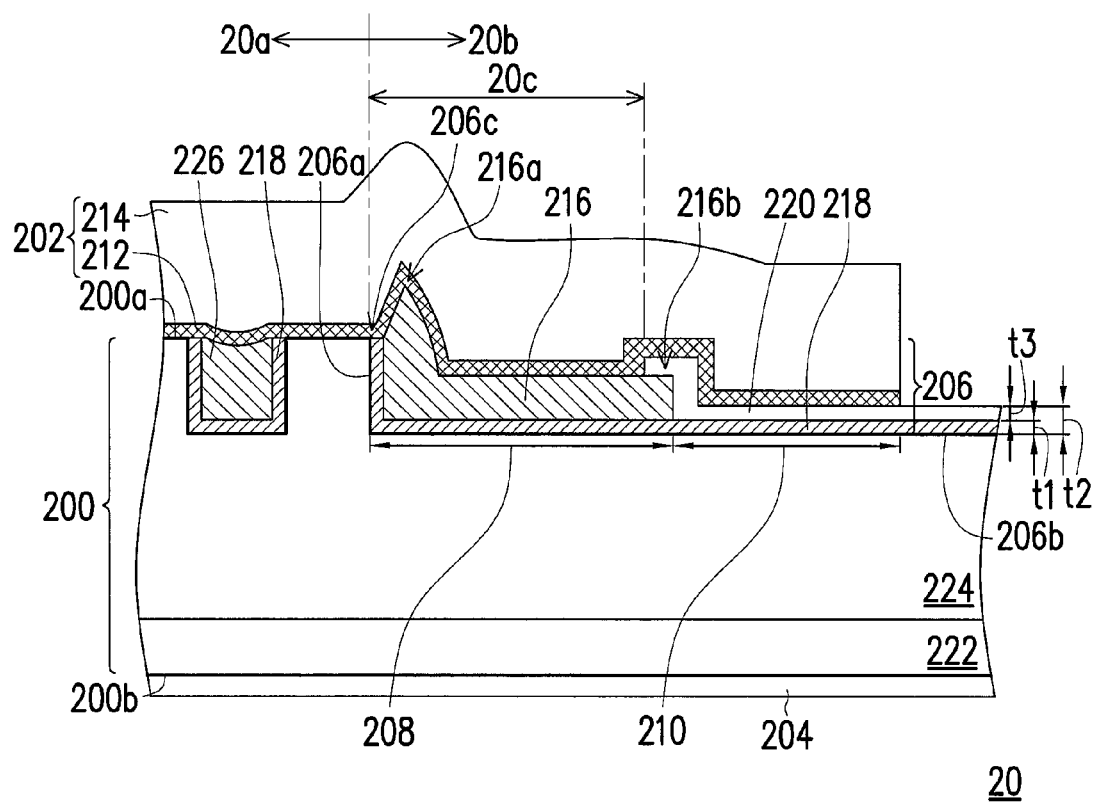
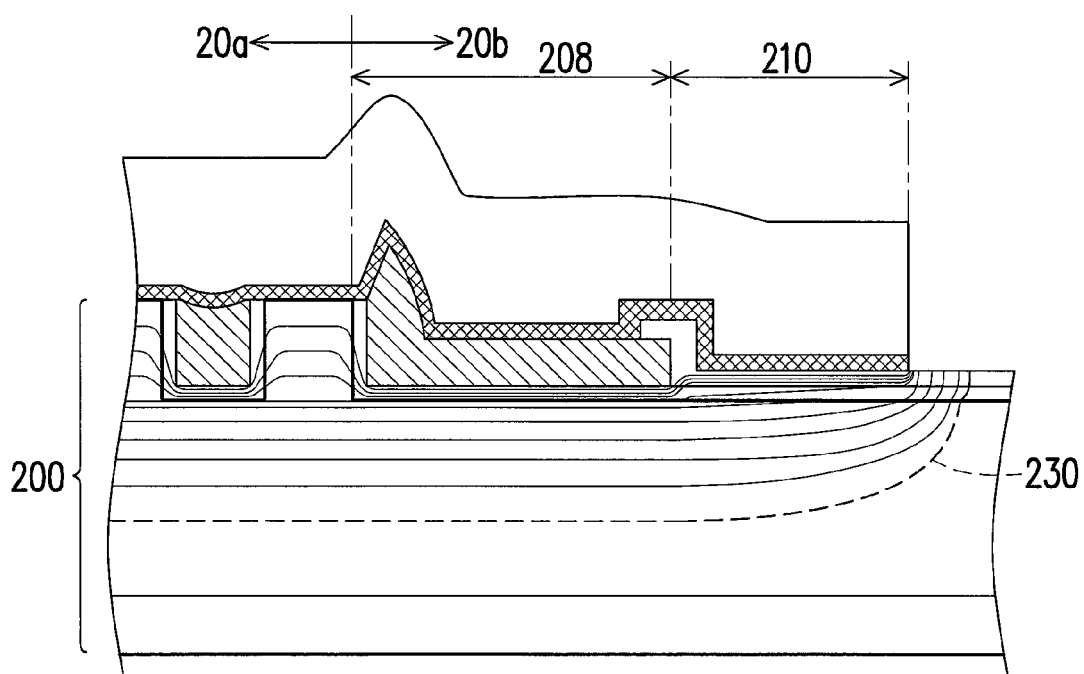


FIG. 2A



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FIG. 2B

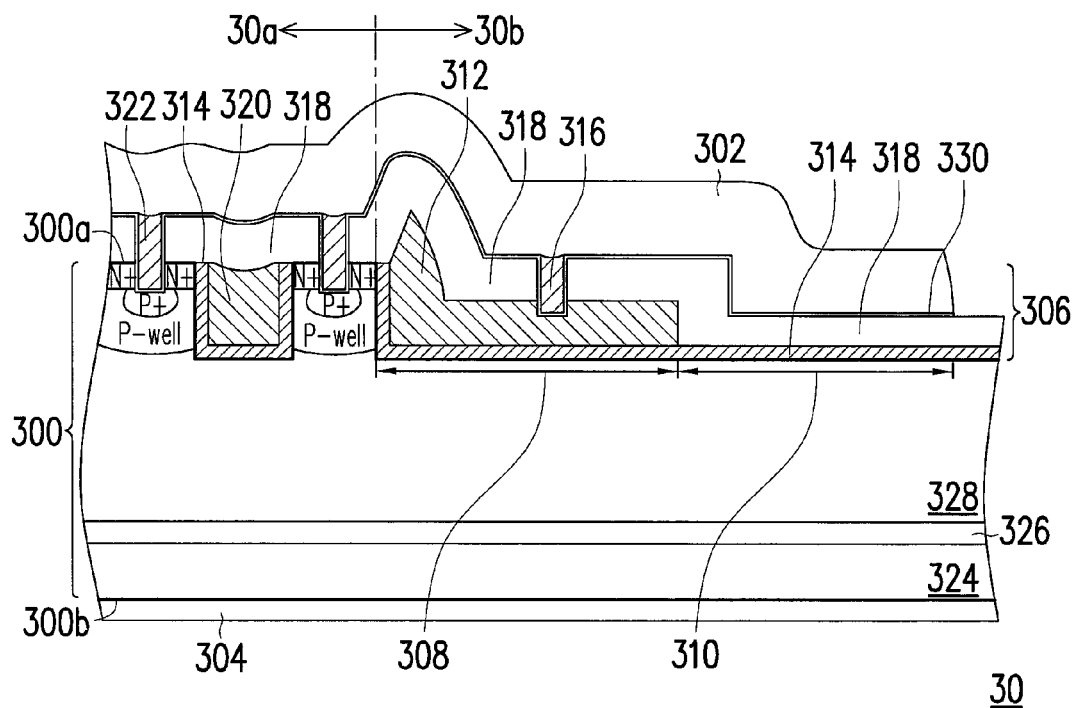


FIG. 3

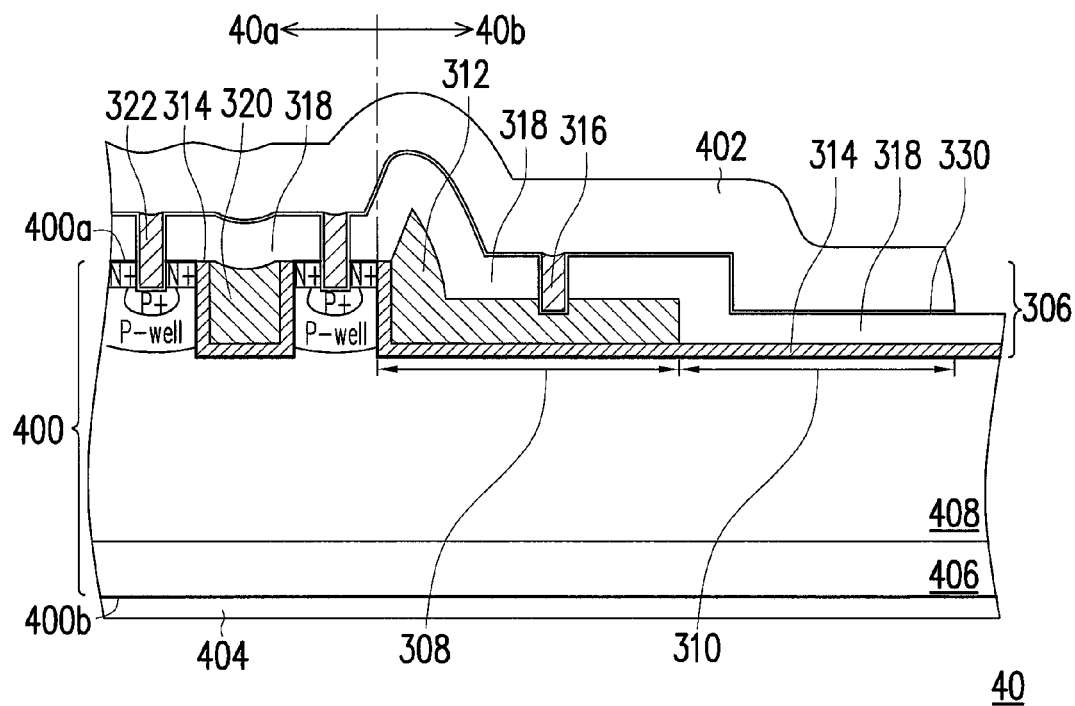


FIG. 4

**POWER SEMICONDUCTOR DEVICE AND  
EDGE TERMINAL STRUCTURE THEREOF  
INCLUDING AN L-SHAPED  
ELECTRIC-PLATE**

CROSS-REFERENCE TO RELATED  
APPLICATION

This application claims the priority benefits of Taiwan application serial no. 101118584, filed on May 24, 2012, and Taiwan application serial no. 101209918, filed on May 24, 2012. The entirety of each of the above-mentioned patent applications is hereby incorporated by reference herein and made a part of this specification.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a power semiconductor technique. More particularly, the invention relates to an edge terminal structure of a trench power semiconductor device capable of raising a breakdown voltage.

2. Description of Related Art

A power semiconductor device is often applied to a switch mode power supply or other high-speed power switches. According to requirements of the power semiconductor device, an active area of the device needs to allow large current to pass through, and the terminal area of the device needs to withstand large breakdown voltage.

At present, several power semiconductor devices (e.g., the barrier Schottky diode) have been developed and employed. Since the breakdown voltage of the normal planar barrier Schottky diode is not high enough, a trench metal oxide semiconductor barrier Schottky (TMBS) diode shown in FIG. 1 has been developed recently.

With reference to FIG. 1, in the TMBS diode 10, an N-epitaxial layer 102 is formed on an N<sup>+</sup> substrate 100, a plurality of trench gates 104 are formed in the N-epitaxial layer 102, and a gate oxide layer 106 is configured between the trench gates 104 and the N-epitaxial layer 102. A barrier Schottky metal layer 108 and an anode metal 110 are then deposited on a surface of the N-epitaxial layer 102 and surfaces of the trench gates 104.

FIG. 1 merely illustrates the structure of an active area, and how to design an edge terminal structure adapted to the TMBS diode 10 has become one of the key research topics in various fields. For instance, U.S. Pat. No. 6,309,929 and U.S. Pat. No. 6,396,090 have both disclosed similar concepts.

In addition to the TMBS diode, other power semiconductor devices such as a trench power metal oxide semiconductor field effect transistor (MOSFET), a trench insulated gate bipolar transistor (IGBT), etc. have also encountered the same issues.

SUMMARY OF THE INVENTION

The invention is directed to an edge terminal structure of a trench power semiconductor device capable of raising a breakdown voltage.

The invention is further directed to a trench power semiconductor device having an edge terminal structure which is capable of raising a breakdown voltage.

In an embodiment of the invention, an edge terminal structure of a trench power semiconductor device is provided. The edge terminal structure includes a substrate, a first electrode and a second electrode respectively disposed on a surface and a back of the substrate, a first field plate, and a second field

plate. The trench power semiconductor device includes an active area and an edge terminal area, and a trench is located in a surface of the substrate in the edge terminal area beside the active area. The first field plate disposed on a sidewall of the trench extends toward a tail of the trench and includes at least an L-shaped electric-plate, a gate insulation layer below the L-shaped electric-plate, and the first electrode on the L-shaped electric-plate. The second field plate includes at least an insulation layer and the first electrode above the insulation layer. The insulation layer covers the tail of the trench and extends at least to cover a tail of the L-shaped electric-plate.

According to an embodiment of the invention, if the trench power semiconductor device is a TMBS diode, the first electrode is in direct contact with a surface of the L-shaped electric-plate, and the substrate includes a first conductive-type substrate and a first conductive-type epitaxial layer formed on the first conductive-type substrate.

According to an embodiment of the invention, if the trench power semiconductor device is the TMBS diode, a thickness of the insulation layer of the second field plate is greater than a thickness of the gate insulation layer of the first field plate.

According to an embodiment of the invention, if the trench power semiconductor device is the TMBS diode, a total thickness of the insulation layer of the second field plate and the gate insulation layer is greater than a thickness of the gate insulation layer of the first field plate when the gate insulation layer extends below the insulation layer of the second field plate.

According to an embodiment of the invention, if the trench power semiconductor device is the TMBS diode, the second electrode is a cathode, and the first electrode includes a barrier Schottky metal layer and an anode metal layer disposed on the barrier Schottky metal layer.

According to an embodiment of the invention, if the trench power semiconductor device is a trench IGBT, the insulation layer completely covers the L-shaped electric-plate, and the substrate includes a second conductive-type substrate, a first conductive-type buffer layer formed on the second conductive-type substrate, and a first conductive-type epitaxial layer formed on the first conductive-type buffer layer.

According to an embodiment of the invention, if the trench power semiconductor device is the trench IGBT, the first electrode is an emitter, and the second electrode is a collector.

According to an embodiment of the invention, if the trench power semiconductor device is the trench IGBT, the edge terminal structure further has a conductive plug that passes through the insulation layer and is electrically connected to the first electrode and the L-shaped electric-plate. Besides, a barrier layer is located on a surface of the insulation layer and located among the conductive plug, the first electrode, the L-shaped electric-plate, and the insulation layer.

According to an embodiment of the invention, if the trench power semiconductor device is a trench power MOSFET, the insulation layer completely covers the L-shaped electric-plate, and the substrate includes a first conductive-type substrate and a first conductive-type epitaxial layer formed on the first conductive-type substrate.

According to an embodiment of the invention, if the trench power semiconductor device is the trench power MOSFET, the first electrode is a source, and the second electrode is a drain.

According to an embodiment of the invention, if the trench power semiconductor device is the trench power MOSFET, the edge terminal structure further has a conductive plug that passes through the insulation layer and is electrically connected to the first electrode and the L-shaped electric-plate.

Besides, a barrier layer is located on a surface of the insulation layer and located among the conductive plug, the first electrode, the L-shaped electric-plate, and the insulation layer.

In an embodiment of the invention, a trench power semiconductor device having the aforesaid edge terminal structure is provided. The trench power semiconductor device further includes a plurality of trench gates located in the surface of the substrate in the active area, and the first electrode is also located on the surface of the substrate in the active area.

According to an embodiment of the invention, if the trench power semiconductor device is a trench IGBT or a trench power MOSFET, the trench power semiconductor device not only has a conductive plug electrically connected to the first electrode and the L-shaped electric-plate but also includes another conductive plug that passes through the insulation layer and is electrically connected to the first electrode and the source region in the active area. Besides, a barrier layer is located on a surface of the insulation layer and located among the two conductive plugs, the first electrode, the L-shaped electric-plate, and the insulation layer.

In view of the above, not only the first field plate is formed in the edge terminal structure of the trench power semiconductor device, the second filed plate (e.g., a metal electrode) covering the first field plate and extending outward is also applied. Thereby, the breakdown voltage of the device may be increased.

Other features and advantages of the invention will be further understood from the further technological features disclosed by the embodiments of the invention wherein there are shown and described preferred embodiments of this invention, simply by way of illustration of modes best suited to carry out the invention.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are included to provide further understanding, and are incorporated in and constitute a part of this specification. The drawings illustrate exemplary embodiments and, together with the description, serve to explain the principles of the invention.

FIG. 1 is a schematic view illustrating a conventional TMBS diode.

FIG. 2A is a schematic cross-sectional view illustrating a TMBS diode according to a first embodiment of the invention.

FIG. 2B illustrates a location of a depletion region in the TMBS diode shown in FIG. 2A.

FIG. 3 is a schematic cross-sectional view illustrating a trench IGBT according to a second embodiment of the invention.

FIG. 4 is a schematic cross-sectional view illustrating a trench power MOSFET according to a third embodiment of the invention.

#### DETAILED DESCRIPTION OF DISCLOSED EMBODIMENTS

In an embodiment of the invention, an edge terminal structure of a trench power semiconductor device is provided, and the edge terminal structure is applicable to a TMBS diode, a trench IGBT, a trench power MOSFET, or the like trench power semiconductor device. Several embodiments are provided below to elaborate the edge terminal structure.

FIG. 2A is a schematic cross-sectional view illustrating a TMBS diode according to a first embodiment of the invention. In FIG. 2A, the TMBS diode 20 includes an active area 20a and an edge terminal area 20b.

With reference to FIG. 2A, the TMBS diode 20 basically includes a substrate 200, a first electrode 202 (i.e., the anode), and a second electrode 204 (i.e., the cathode). The first electrode 202 is located on a surface 200a of the substrate 200, and the second electrode 204 is disposed on a back 200b of the substrate 200. A trench 206 is formed in the surface 200a of the substrate 200 in the edge terminal area 20b beside the active area 20a. A first field plate 208 and a second field plate 210 are disposed in the trench 206. The first field plate 208 is located on a sidewall 206a of the trench 206 and extends toward a tail 206b of the trench 206. The first electrode 202 includes a barrier Schottky metal layer 212 and an overlying anode metal layer 214. Besides, the first electrode 202 extends from the active area 20a to the tail 206b of the trench 206 and covers the first field plate 208. Therefore, a length of the first field plate 208 is less than that of the first electrode 202 in the edge terminal area 20b. For instance, the length of the first field plate 208 is at least 5  $\mu\text{m}$  approximately, e.g., 5  $\mu\text{m}$ -20  $\mu\text{m}$ , but the invention is not limited thereto. The anode metal layer 214 is made of a metal material, such as AlSiCu or the like.

As shown in FIG. 2A, the first field plate 208 includes an L-shaped electric-plate 216, a gate insulation layer 218 below the L-shaped electric-plate 216, and the anode metal layer 214 above the L-shaped electric-plate 216. Here, a top side 216a of the L-shaped electric-plate 216 is higher than a top 206c of the trench 206. The L-shaped electric-plate 216 is made of polysilicon, for instance. The second field plate 210 includes at least an insulation layer 220 and the anode metal layer 214 above the insulation layer 220. The insulation layer 220 covers the tail 206b of the trench 206 and extends at least to cover a tail 216b of the L-shaped electric-plate 216. Here, the insulation layer 220 may be made of a material suitable for forming an inner-layer dielectric (ILD) layer. The second field plate 210 is electrically connected to the first field plate 208 through a terminal area contact window 20c. Hence, the length of the first field plate 208 is slightly greater than that of the terminal area contact window 20c, and the length of the second field plate 210 is at least 5  $\mu\text{m}$  approximately, e.g., 5  $\mu\text{m}$ -20  $\mu\text{m}$ , but the invention is not limited thereto. Thereby, the depletion region of the TMBS diode 20 may be expanded toward the edge of the device according to the first and second field plates 208 and 210, so as to further increase the breakdown voltage.

As indicated in FIG. 2A, the gate insulation layer 218 of the first field plate 208 extends below the insulation layer 220 of the second field plate 210, a thickness t1 of the gate insulation layer 218 of the first field plate 208 is apparently less than the total thickness t2 of the insulation layer 220 and the gate insulation layer 218 of the second field plate 210. However, if the gate insulation layer 218 of the first field plate 208 does not extend below the insulation layer 220 of the second field plate 210, the thickness t1 of the gate insulation layer 218 should also be less than the thickness t3 of the insulation layer 220. Since the insulation layer 220 of the second field plate 210 with the relatively large thickness may withstand greater voltage difference than the gate insulation layer 218 with the relatively small thickness, the breakdown voltage in the edge terminal area 20b may be further increased.

The substrate 200 shown in FIG. 2A includes a first conductive-type substrate 222 (e.g., the N+ substrate) and the first conductive-type epitaxial layer 224 (e.g., the N-epitaxial layer) formed on the first conductive-type substrate 222. The first electrode 202 is in direct contact with a surface of the substrate 200a in the active area 20a, and the active area 20a has at least one trench gate 226 therein. For example, the

trench gate **226** has a structure constituted by polysilicon or metal, but the invention is not limited thereto.

FIG. 2B illustrates a location of a depletion region in the TMBS diode **20** shown in FIG. 2A when the anode voltage is grounded and the cathode voltage is greater than 0 V (i.e., the reverse bias). The thickness of the insulation layer (and the gate insulation layer) of the second field plate **210** is relatively large, and it may withstand a relatively great voltage difference. Accordingly, the second field plate **210** allows the depletion region in the substrate **200** to be expanded toward the edge of the device. This may also be proven by the potential lines in the depletion region **230** and below the first field plate **208** and the second field plate **210**. Therefore, the breakdown voltage of the device may be increased.

FIG. 3 is a schematic cross-sectional view illustrating a trench IGBT according to a second embodiment of the invention. In FIG. 3, the trench IGBT **30** includes an active area **30a** and an edge terminal area **30b**.

With reference to FIG. 3, the trench IGBT **30** basically includes a substrate **300**, a first electrode **302** (i.e., an emitter) located on a surface **300a** of the substrate **300**, and a second electrode **304** (i.e., a collector) located on a back **300b** of the substrate **300**. The first electrode **302** is located on the surface **300a** of the substrate **300**, and the second electrode **304** is disposed on the back **300b** of the substrate **300**. Here, the second electrode **304** is made of a metal material, e.g., Ti/Ni/Ag or the like. A trench **306** is formed in the surface **300a** of the substrate **300** in the edge terminal area **30b** beside the active area **30a**. A first field plate **308** and a second field plate **310** are disposed in the trench **306**. The first electrode **302** extends from the active area **30a** to the trench **306** and covers the first field plate **308**, and thus the length of the first field plate **308** is less than the length of the first electrode **302** in the edge terminal area **30b**. The first field plate **308** includes an L-shaped electric-plate **312**, a gate insulation layer **314** below the L-shaped electric-plate **312**, and the first electrode **302** above the L-shaped electric-plate **312**. The first electrode **302** is electrically connected to the L-shaped electric-plate **312** through at least one first conductive plug **316**. The L-shaped electric-plate **312** is made of polysilicon, for instance, and the location and the shape of the L-shaped electric-plate **312** are the same as those of the L-shaped electric-plate described in the first embodiment. The first conductive plug **316** is a tungsten plug, for instance.

With reference to FIG. 3, the second field plate **310** includes at least an insulation layer **318** and the first electrode **302** above the insulation layer **318**. The insulation layer **318** covers the tail of the trench **306** and completely covers the L-shaped electric-plate **312**. Here, the insulation layer **318** may be made of a material suitable for forming an ILD layer. The first electrode **302** of the second field plate **310** is electrically connected to the L-shaped electric-plate **312** of the first field plate **308** through the first conductive plug **316**. At least one trench gate **320** is located in the surface **300a** of the substrate **300** in the active area **30a**. For example, the trench gate **320** has a structure constituted by polysilicon or metal, but the invention is not limited thereto. The insulation layer **318** completely covers the trench gate **320** in the active area **30a**. The first electrode **302** may be electrically connected to N+ source region within the substrate **300** in the active area **30a** through at least one second conductive plug **322** that passes through the insulation layer **318**. The second conductive plug **322** is a tungsten plug, for instance. The substrate **300** includes a second conductive-type substrate **324** (e.g., the P+ substrate), a first conductive-type buffer layer **326** (e.g., the N+ buffer layer) formed on the second conductive-type substrate **324**, and a first conductive-type epitaxial layer **328**

(e.g., the N-epitaxial layer) formed on the first conductive-type buffer layer **326**. The gate insulation layer **314** may further extend below the insulation layer **318** of the second field plate **310**. The gate insulation layer **314** is also located between the trench gate **320** and the first conductive-type epitaxial layer **328**. Besides, a barrier layer **330** is located on a surface of the insulation layer **318** and located among the conductive plugs **316** and **322**, the first electrode **302**, the L-shaped electric-plate **312**, and the insulation layer **318**, and the barrier layer **330** is made of Ti/TiN, for instance.

FIG. 4 is a schematic cross-sectional view illustrating a trench power MOSFET according to a third embodiment of the invention. In FIG. 4, the trench power MOSFET **40** including an active area **40a** and an edge terminal area **40b** is shown, and the reference symbols and numbers shown in FIG. 3 are also employed herein to represent the same or similar components.

With reference to FIG. 4, the trench power MOSFET **40** basically includes a substrate **400**, a first electrode **402** (i.e., a source) located on a surface **400a** of the substrate **400**, and a second electrode **404** (i.e., a drain) located on a back **400b** of the substrate **400**. The substrate **400** described in the present embodiment includes a first conductive-type substrate **406** (e.g., the N+ substrate) and the first conductive-type epitaxial layer **408** (e.g., the N-epitaxial layer) formed on the first conductive-type substrate **406**. Since other components in the third embodiment are the same or similar to those in the second embodiment, detailed descriptions thereof are omitted.

To sum up, in the structural design described in the embodiments of the invention, the length and the thickness of the electric-plate in the edge terminal area are both increased, so as to expand the depletion region. Moreover, the breakdown voltage is further increased.

It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the disclosed embodiments without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the invention cover modifications and variations of this invention provided they fall within the scope of the following claims and their equivalents.

What is claimed is:

1. An edge terminal structure of a trench power semiconductor device, wherein the power semiconductor device comprises an active area and an edge terminal area, the edge terminal structure comprising:

- a substrate, wherein a trench being located in a surface of the substrate in the edge terminal area beside the active area;
- a first electrode located on the surface of the substrate and extends from the active area to the trench;
- a second electrode located on a back of the substrate;
- a first field plate disposed on a sidewall of the trench and extending toward a tail of the trench, wherein the first field plate comprises at least an L-shaped electric-plate, a gate insulation layer below the L-shaped electric-plate, and the first electrode on the L-shaped electric-plate, wherein the L-shaped electric-plate has a tail end in the trench away from the sidewall of the trench; and
- a second field plate disposed within the trench outside the L-shaped electric-plate, the second field plate comprises a portion of the first electrode and at least an insulation layer between the portion of the first electrode and the substrate, wherein the insulation layer covers the tail of the trench and extends to cover only a portion of the tail end of the L-shaped electric-plate, and the gate insulation layer is further disposed below the insulation layer



7

outside the L-shaped electric-plate, and a length of the second field plate is 5  $\mu\text{m}$ -20  $\mu\text{m}$  such that a depletion region is formed and expanded according to the length of the second field plate.

2. The edge terminal structure of the trench power semiconductor device as recited in claim 1, wherein the trench power semiconductor device is a trench metal oxide semiconductor barrier Schottky diode, the first electrode is in direct contact with a surface of the L-shaped electric-plate, and the substrate comprises:

- a first conductive-type substrate; and
- a first conductive-type epitaxial layer formed on the first conductive-type substrate.

3. The edge terminal structure of the trench power semiconductor device as recited in claim 2, wherein the second electrode is a cathode, and the first electrode comprises:

- a barrier Schottky metal layer; and
- an anode metal layer disposed on the barrier Schottky metal layer.

4. The edge terminal structure of the trench power semiconductor device as recited in claim 2, wherein a thickness of the insulation layer of the second field plate is greater than a thickness of the gate insulation layer of the first field plate.

5. The edge terminal structure of the trench power semiconductor device as recited in claim 2, wherein the gate insulation layer further extends below the insulation layer of the second field plate, and a total thickness of the insulation layer of the second field plate and the gate insulation layer is greater than a thickness of the gate insulation layer of the first field plate.

6. A trench power semiconductor device having an active area and an edge terminal area and comprising:

- a substrate, a trench being formed on a surface of the substrate in the edge terminal area beside the active area;
- a trench gate located in the surface of the substrate in the active area;
- a first electrode located at the active area and on the surface of the substrate in the edge terminal area, wherein the first electrode covers the trench gate and extends from the active area to the trench;
- a second electrode located on a back of the substrate;
- a first field plate disposed on a sidewall of the trench and extending toward a tail of the trench, the first field plate comprises at least an L-shaped electric-plate, a gate

8

insulation layer below the L-shaped electric-plate, and the first electrode on the L-shaped electric-plate, wherein the L-shaped electric-plate has a tail end in the trench away from the sidewall of the trench; and

a second field plate disposed within the trench outside the L-shaped electric-plate, the second field plate comprises a portion of the first electrode and at least an insulation layer between the portion of the first electrode and the substrate, wherein the insulation layer covers the tail of the trench and extends to cover only a portion of the tail end of the L-shaped electric-plate, and the gate insulation layer is further disposed below the insulation layer outside the L-shaped electric-plate, and a length of the second field plate is 5  $\mu\text{m}$ -20  $\mu\text{m}$  such that a depletion region is formed and expanded according to the length of the second field plate.

7. The trench power semiconductor device as recited in claim 6, wherein the trench power semiconductor device is a trench metal oxide semiconductor barrier Schottky diode, the first electrode is in direct contact with a surface of the L-shaped electric-plate, and the substrate comprises:

- a first conductive-type substrate; and
- a first conductive-type epitaxial layer formed on the first conductive-type substrate.

8. The trench power semiconductor device as recited in claim 7, wherein the second electrode is a cathode, and the first electrode comprises:

- a barrier Schottky metal layer; and
- an anode metal layer disposed on the barrier Schottky metal layer.

9. The trench power semiconductor device as recited in claim 7, wherein a thickness of the insulation layer of the second field plate is greater than a thickness of the gate insulation layer of the first field plate.

10. The trench power semiconductor device as recited in claim 7, wherein the gate insulation layer further extends below the insulation layer of the second field plate, and a total thickness of the insulation layer of the second field plate and the gate insulation layer is greater than a thickness of the gate insulation layer of the first field plate.

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